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(71) Applicant: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
Kadoma-shi, Osaka-fu, 571 (JP)

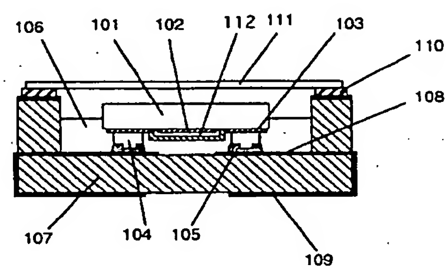
(72) Inventors:
- Onishi, Keiji
  Settu-shi, Osaka 566 (JP)
- Seki, Shun-ichi
  Amagasaki-shi, Hyougo 661 (JP)
- Taguchi, Yutaka
  Takatsuki-shi, Osaka 569 (JP)
- Eda, Kazuo
  Nara-shi, Nara 631 (JP)

(74) Representative: Grünecker, Kinkeldey, Stockmair & Schwanhäusser
Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) An acoustic surface-wave device and its manufacturing method

(57) The objects of this invention are to offer a compact, low height, low cost, and high reliability acoustic surface-wave device, and its manufacturing method. In order to accomplish the objects of the invention, the invented acoustic surface-wave device is constituted of a substrate (101), comb-electrode (102) disposed on the main surface of said substrate plural electrode pads (103) disposed around said comb-electrode, protecting means (112) covering said comb-electrode through a closed space produced by combining said comb-electrode and said plural electrode pads with said substrate by using substantially covalent bonding force acted between, conductive bumps (104) formed on said plural electrode bumps, a conductive adhesive layer (105) disposed at least on the top of said conductive bumps, and a package (107) adhered on said conductive bumps by means of said conductive adhesive, and insulation adhesive filled into said package contacting with said conductive adhesive, said conductive bumps, and said protective means.

Fig. 1



EP 0 742 643 A1

Description

BACKGROUND OF THE INVENTION

This invention relates to an acoustic surface-wave device to be employed in mobile communication equipment or such.

In accordance to the rapid development of mobile communication systems, the compact, low-height, high performance acoustic surface-wave device which is one of the key devices constituting the communication equipment, is now strongly desired.

Although the wire-bonding method had been widely employed in assembling said acoustic surface-wave device, the miniaturization of acoustic surface-wave device is limited because of a large wire bonding land area required for this. In addition to this, a short-circuit problem caused by the introduction of conductive foreign objects such as solder particles on the unprotected comb electrode had been produced often. Therefore, a new face-down assembly method such as the method reported in Proceedings on 1993 Japan LEMT Symposium (1993), pp. 109 - 112, had been experimented.

A structure of conventional acoustic surface-wave device assembled by means of said face-down method is now explained by referring to Fig. 7 showing a cross-section of conventional acoustic surface-wave device. In Fig. 7, 201 is a substrate, 202 is comb-electrode, 203 is electrode pad, 204 is conductive bump, 205 is conductive adhesive, 206 is insulating adhesive, 207 is package, 208 is electrode pattern, 209 is external electrode, 210 is sealing, and 211 is a cover.

As shown in the conventional acoustic surface-wave device, conductive bump 204 is disposed first on electrode pad 203 disposed on substrate 201, conductive adhesive 205 is transfer-coated on said conductive bump 204, and device is assembled on electrode pattern 208 disposed on package 207 made of alumina, glass-ceramics, or other materials by means of said face-down method in order to establish an external electrical conduction.

In this structure of the device, since the adhesion strength between substrate 201 and package 207 established only by said conductive bump 204 and conductive adhesive 205 is considered inadequate, it is reinforced by providing insulating adhesive 206.

However, in order to avoid any ill-effects on said surface-wave device, a method applying a high-viscosity insulating adhesive 206 except the peripheral region of said comb-electrode 202 had been employed in order to avoid the blocking of surface-wave propagation at the area around said comb-electrode 202 .

However, although the assembling of said acoustic surface wave device by said face-down method is definitely advantageous for the device miniaturization since no wire bonding lands had to be provided, the exact control of application of insulating adhesive had been left as a difficult problem since there are chances of intrusion of insulating adhesive employed to reinforce the adhesive strength of acoustic surface-wave device into the comb-electrode. That is, since the assembling work of acoustic surface-wave device has to be carried out under a strictly controlled environment protecting the comb-electrode against the intrusion of foreign objects from outside, the practical application of conventional assembling technology had been difficult.

Thus, another conventional face-down bonding method applicable to assemble the acoustic surface wave devices had been reported in Proceedings on 1994 Ultrasonic Symposium (1994), pp. 159 - 162. That means that, without using the reinforcement of insulation adhesive, said conductive bumps and said electrode disposed on the package are directly bonded by means of heat and ultrasonic energy holding said acoustic surface-wave device only by means of conductive bumps. Since this is a method without the use of insulation adhesive, the problems of such including the intrusion of adhesive into said comb-electrode can be solved.

However, another problem such as an ill effect to said acoustic surface-wave device caused by the thermal stress produced by the thermal expansion coefficient difference between said acoustic surface-wave device and the package is possible instead. Therefore, the practical application of these face-down bonding methods having an advantage of compact and low height packaging have been considered very difficult.

ABSTRACT OF THE INVENTION

The objects of the present invention is to solve these conventional problems, and to offer a compact and low height acoustic surface-wave device, and at the same time, to offer a new manufacturing method thereof.

In order to accomplish these objects, the invented acoustic surface-wave device is constituted of a substrate, comb-electrode disposed on the main surface of said substrate, plural electrode pads disposed around said comb-electrode, protecting means covering said comb-electrode by means of a closed space produced by bonding said comb-electrode and said plural electrode pads with said substrate by utilizing substantially covalent bonding force acted there-between, conductive bumps formed on said plural electrode bumps, a conductive adhesive layer disposed at least on the top of said conductive bumps, a package adhered on said conductive bumps by means of said conductive adhesive, and a package filled with said conductive adhesive contacting with said conductive bumps, said protective means. and said package.

In addition to these, the invented manufacturing method consists of a process to form a comb-electrode on a substrate, a process to form plural electrode pads around said comb electrode disposed on said substrate, a process to bond said substrate and said protecting means covering said comb-electrode and said plural pads by means of a closed space produced between

said electrode pads and said comb-electrode by means of a substantially covalent bonding force, a process to form conductive bumps on said plural electrode pads, a process to form a conductive adhesive layer at least on the top of said conductive bumps, and a process to bond said conductive bumps onto an electrode pattern disposed on said package by means of said conductive adhesive, and a process to fill said conductive adhesive in contact with said conductive bumps, said conductive adhesive layer, said protecting means, and said package.

By taking an embodiment of thus constructed acoustic surface-wave device and a manufacturing method thereof, the advantages of compact and low-height device easily attained by employing a face-down bonding method are now explained below.

Since the package is filled with an insulation adhesive while protecting the comb-electrode by means of a protecting means, no viscosity adjustment of insulation adhesive has to be made, so that the coating process can be simplified and the manufacturing method of acoustic surface-wave device can be performed at lower cost. Moreover, since this is an assembling method without the use of heat or ultrasonic energy, there should be no chances harming the characteristics of acoustic surface-wave device.

Moreover, by combining said protective means with said substrate by means of a covalent bonding method, an acoustic surface wave derive of very high reliability without the chances of intrusions of conductive foreign materials, water vapor, or such from outside can be obtained, and moreover, a high frequency module incorporating another high-frequency device or plural acoustic surface-wave devices can be easily obtained.

Since an air-tight sealing can be obtained by said protecting means, the assembly work of acoustic surface-wave device is no longer essential by mounting the acoustic surface device elements on said package means, and since a substantial reduction of the dimension of acoustic surface-wave device is possible also, this may contribute largely to the device miniaturization.

BRIEF EXPLANATION OF THE DRAWINGS

The several structures of invented acoustic surface-wave devices are now explained below by referring the attached drawings.

Figure 1 shows a cross-section of acoustic surface-wave device of Embodiment-1, showing its schematic structure.

Figure 2 shows a cross-section of the acoustic surface-wave device of Embodiment-1, showing its schematic structure at the peripheral of assembled part.

Figure 3 shows a cross-section of the acoustic surface-wave device of Embodiment-2, showing its schematic structure at the peripheral of assembled part.

Figure 4 shows a cross-section of the acoustic surface-wave device of Embodiment-3, showing its schematic structure at the peripheral of assembled part.

Figure 5 shows a cross-section of the acoustic surface-wave device of Embodiment-4, showing its schematic structure at the peripheral of assembled part.

Figure 6 shows a cross-section of the acoustic surface-wave device of Embodiment-5, showing its schematic structure at the peripheral of assembled part.

Figure 7 shows a cross-section of the contentional acoustic surface-wave device, showing its schematic structure.

DETAILED EXPLANATION OF THE INVENTION

The structures of the invented acoustic surface-wave devices are now explained below by referring the attached drawings.

EMBODIMENT-1

Figure 1 shows a cross-section of acoustic surface-wave device of Embodiment-1, showing its schematic structure. In Fig. 1, 101 is a substrate, 102 is a comb-electrode, 103 is electrode pads, 104 is conductive bumps, 105 is conductive adhesive, 106 is insulating adhesive, 107 is a package, 108 is electrode pattern, 109 is an external electrode, 110 is sealing, 111 is a cover, and 112 is a protective means.

Figure 2 shows a cross-section of the acoustic surface-wave device of Embodiment-1, showing its schematic structure at the peripheral of assembled part.

In Fig. 2, 101 is a substrate, 102 is a comb-electrode, 103 is electrode pads, 104a is a top of said conductive bump, 104b is a base of said conductive bump, 105 is conductive adhesive, 106 is insulating adhesive, 107 is a package, 108 is an electrode pattern, 112 is a protective means, 112 is a protective means, and 113 is a direct bonding part.

In Embodiment-1, a 36° Y-cut X-propagation lithium tantalate crystal is used as substrate 101, comb-electrode 102 and electrode pad are made of metal thinfilm made mainly of gold patterned by using a conventional photolithographic method combined with a lift-off method. However, the substrate material to which the embodiments of the invention are applicable is not limited to the lithium tantalate crystal but is applicable to other crystals such as lithium niobate, quartz, lithium borate .

Embodiment-1 is characterized by direct bonding of protecting means 112 protecting said comb-electrode of acoustic surface wave device onto substrate 101. In here, said direct bonding means covalent bonding performed at a substantially atomic level in bonding two different substrates together.

The reason for employing the direct bonding for Embodiment-2 is to obtain a high degree air-tightness at the peripheral of comb-electrode since the characteristics of acoustic surface wave device is influenced much by the condition of comb electrode. For example, the characteristics of acoustic surface-wave device is deteriorated easily by the moisture adsorbed in said comb

electrode at the process of substrate dicing performed at the poor air-tightness. Moreover, if the air-tightness is not maintained properly allowing the intrusion of moisture after the device assembling, the device reliability would be lost because of the slow deterioration of device characteristics.

Therefore, the introduction of direct bonding technology enabling the bonding two components at an atomic level, is essential in these embodiments, and by using this device, a highly reliable acoustic surface-wave device would be realized.

Although the direct bonding is a bonding technology applicable for the bonding of two different substrates, a square single-crystal substrate having a cut angle same as that of substrate 101 is employed as the material of protection means 112 in here in order to establish a crystallographic consistency with substrate 101.

This is because that the characteristics of acoustic surface wave device may well be influenced by the lattice distortion caused by the difference of lattice constants or residual stress caused by the different thermal expansion coefficients, since the direct bonding of substrates is performed at an atomic level. Furthermore, this is because that substrate 101 and protection means 112 shall desirably be of same materials since the adequate bonding strength could not be obtained otherwise.

The invented manufacturing method of acoustic surface-device is now explained below. An indentation having a depth of about 10 μm is formed on an area of protection means 112 facing to comb-electrode 102 disposed on substrate 101 by using a fluoro-nitric acid system etchant providing a specific space to comb-electrode 102, ensuring free-propagation of acoustic surface-wave.

Although only an example where said indentation is formed by a fluoro-nitric acid system etchant is shown here, a mechanical method such as sand-blasting may also be used to form said indentation. The depth of said indentation may be less than 10 μm considering the thickness of comb-electrode 102 so far as the propagation of acoustic surface-wave is not disturbed. The wall thickness of protection means 112, that is, bonding width 103 can be an order of 250 μm.

Then, direct bonding of said substrate 101 onto said protection means 112 is performed. After mirror-finishing the bonding face first, substrate 101 and protection means 112 are washed, and a hydrophilic processing using a mixed liquid of aqueous hydrogen peroxide and aqueous ammonia is applied thereon.

Then, substrate 101 and protection means 112 are aligned and pressed together. By this, bonding bounded by water molecules is established. Finally, the direct bonding process establishing a covalent bonding between substrate 101 and protection means 112 is ended by applying a heat treatment of about 200°C expelling the water molecules remaining on the boundary.

Then, conductive bumps 104 are deposited on electrode pads 103 disposed on said substrate by using a ball-bonding method employing gold wire. In this bump forming process, the employment of wet-process such as an electroplating is undesirable since acoustic surface-wave device 101 is a device sensitive to water molecules, and the employment of dry-process using gold bumps is desirable instead.

At the final process, conductive bumps 104 are pressed on the mirror-finished base at a load of about 50 grams per bump in order to obtain plural conducting bumps having uniformly leveled tops.

Fig. 2 shows a cross-section of said direct bonding, showing a peripheral structure thereof. As shown in Fig. 2, the obtained conductive bump 104 has a double-protrusion structure consisted of top 104a and base 104b. Then, top 104a of said conductive bump is immersed into a layer of phenoxy-system thermo-plastic conductive adhesive in which silver-paradium alloy particles are dispersed, coated on a base of the bump in order to transfer said conductive adhesive layer 105 on top 104a of said bump 104.

Then, said substrate 101 is bonded face-down on electrode pattern 108 disposed on an alumina package by means of said conductive adhesive layer 105. Since the embodiment shown in Fig. 2 is a bonding method without the application of heat or ultrasonic energy as shown in Proceedings on 1994 Ultrasonic Symposium, pp. 159 - 162, there should be no problem of adverse effect of thermal stress or such on the characteristics of acoustic surface-wave device.

According to this embodiment of the invention, the height of base 104b of the conductive bump has to be set at a height slightly higher than the height of protective means 112 in order to allow the transfer of conductive adhesive layer 105 on top 104a of the conductive bump.

In this embodiment, the height of base 104b of said conductive bump is 50 μm and the thickness of said protecting means 112 is 40 μm. These are to avoid the chance of adhesion of conductive resin 105 on said protecting means 112, and this is possible if the height of protecting means 112 is higher than the height of base 104b,

Moreover, although the silver-paradium alloy particle is used as a conductive filler of the conductive adhesive in this embodiment, metal filler particles of other type may be used. In addition to this, although phenoxy-system thermo-plastic conductive adhesive is used as a binder of said conductive adhesive in here, a silicon or epoxy resin system thermo-setting adhesive can be used as well.

Since an adequate mechanical strength holding substrate 101 can not be obtained by means of conductive bump 104 and conductive adhesive 105 only, insulating resin 106 is filled completely in said space provided between said protecting means which is directly bonded on said substrate 101 and said package 107 in order to reinforce the adhesion strength by utiliz-

ing the shrinkage stress at hardening. Though a silicon system thermo-setting adhesive is used as insulating resin 106 in this embodiment, needless to day that the same effect can also be obtained by using an epoxy system thermo-setting adhesive.

In this embodiment of the invention, since a space is provided on the comb-electrode of substrate 101 by means of said indentation of protecting means 112, this can be filled completely with low-viscosity insulating adhesive without the adjustment of its viscosity. Since the productivity can be improved and the introduction of foreign material during the assembly process can be prevented, not only the higher production yield but the lower production cost can be obtained.

As above-explained, the invented acoustic surface-wave device is constituted of a comb-electrode formed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, a protection means covering said comb-electrode through a space formed by the substantially covalent bonding established between said comb-electrode and said plural electrode pads, conductive bumps formed the top of said plural electrode pads, conductive adhesive disposed at least on top of said conductive bumps, a package adhered on said conductive bumps by means of said conductive adhesive, and insulating adhesive contacting with said conductive adhesive, said conductive bumps, and said protection means filling said package.

By this, the practical employment of face-down system assembly method is realized obtaining a compact and low-height acoustic surface-wave device easily.

This means, while the viscosity adjustment of insulating resin and its coating process had been difficult in manufacturing the acoustic surface-wave device by the conventional method, with the invented method using said protection means filled completely with low viscosity insulating resin, the production yield can be substantially improved and the production cost can be considerably reduced. Furthermore, by providing said protection means, the chance of introduction of foreign materials into comb-electrode part during the assembly process can be complelety elliminated.

Moreover, as shown in this embodiment, the effect of thermal stress caused by a difference in the thermal expansion coefficients between the substrate and the protection means can be eliminated by employing a single-crystal substrate having a cut same as that of the substrate, so that the acoustic surface-wave device of excellent frequency characteristics can be obtained.

Embodiment-2

Fig. 3 shows a cross-section of the invented acoustic surface-wave device of Embodiment-2, and showing particularly a schematic structure of the device assembled on said substrate. In Fig. 3, 101 is a substrate, 102 is a comb-electrode, 103 is electrode pads, 104a is the top of conductive bump, 104b is the base of said conductive bump, 105 is conductive adhesive, 106 is insulating adhesive, 107 is a package, 108 is an electrode pattern, 112 is a protection means, 113 is a direct bonding part, and 113 is an insulating protection layer.

Like the case of Embodiment-1, a 36° Y-cut X-propagation lithium tantalate crystal is used as substrate 101 and protection means 112 also. However, similar effect can be obtained by using a single crystal substrate of lithium niobate, quartz crystal, lithium borate, or such. On the other hand, comb-electrode 102 and electrode pads 103 of aluminum alloy thinfilm are formed by using a conventional photolithographic method. Then, metal thinfilm as a protection layer is deposited on the peripheral of comb-electrode 102 over said wiring pattern excluding electrode pads 103 and comb-electrode 102. Moreover, a silicon oxide layer acting as an insulating protection layer is deposited for a thickness of about 8000 Å by using a sputtering method. As a material of insulating protection layer 113, silicon may be used instead of silicon oxide.

Like the case of Embodiment-1, an indentation is provided on protection means 112 at an area facing to comb-electrode 102 disposed on substrate 101 by using a fluoro-nitric acid system etchant. The direct bonding of substrate 101 onto protection means 112 is performed by using the method shown in Embodiment-1.

When a comb-electrode made of aluminum alloy thinfilm is used like the case of Embodiment-2, the surface of comb-electrode 102 is corroded in said hydrophilic processing for direct bonding. However, the corrosion of comb-electrode 102 can be prevented by depositing insulating protection layer 113 around comb-electrode 102, so that said direct bonding process can be performed even in a case where comb-electrode is made of aluminum alloy.

Then, conductive bumps 104 are disposed on electrode pads 103 formed on substrate 101 by a method of ball-bonding using gold wire, and conductive adhesive 105 is transfer-coated on said conductive bumps 104 after leveling the height of these. After this, substrate 101 is face-down bonded thereon by using conductive adhesive 105. Since the bonding strength realized by using conductive bump 104 and conductive adhesive 105 only is inadequate to hold down substrate 101, insulating resin 106 is filled in the space between package 107 and protecting means 112 bonded directly on substrate 101 in order to supplement the adhesion strength by using the stress of insulating resin 106 at hardening.

In this process, since comb-electrode 102 disposed on substrate 101 is protected by the space secured by the indentation of protecting means 112, said filling can be made without the viscosity adjustment of insulating resin like the case of conventional face-down bonding, and said space is filled completely by the low-viscosity insulating adhesive, the device productively can be improved considerably. Furthermore, since comb-electrode 102 is covered by insulating protection layer 113,

it can be bonded directly onto said protecting means even when it is made of metal thinfilm such as aluminum alloy which is erroded easily, so that the introduction of conductive foreign objects in the assembling process can be prevented and the production yield of the device can be improved.

As above-described, the acoustic surface-wave device of Embodiment-2 consists of a substrate, comb-electrode disposed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, insulating protection layer disposed on said comb-electrode, protecting means covering said comb-electrode enclosing a space produced by a substantially covalent bonding established between said substrate, said comb-electrode and said plural electrode pads, conductive bumps disposed on said plural electrode pads, conductive adhesive disposed at least on the top of said conductive bumps, a package adhered on said conductive bumps by means of said conductive adhesive, and insulating adhesive filled to contact with said conductive bumps, said protecting means, and said package. By this, the face-down system bonding can be applied even when the comb-electrode made of an aluminum alloy which is easily corroded is employed obtaining a compact and low profile acoustic surface-wave device easily.

This means that the viscosity adjustment and coating of insulating resin which had been difficult in the conventional process assembling the acoustic surface-wave device is eliminated, and low viscosity insulating resin is filled in the space provided below the protecting means so that the production yield can be higher while the production cost can be lowered. By providing the protecting means, introduction of conductive foreign objects during the assembling process can be prevented.

Like the case of Embodiment-2, by using a protecting means made of a single crystal substrate having a cut angle same as that of the substrate, the thermal stress due to the difference in the thermal expansion coefficients between the substrate and the protecting means can be eliminated so that the acoustic surface-wave device of excellent frequency characteristics can be obtained.

Embodiment-3

Fig. 4 shows a cross-section of the invented acoustic surface-wave device of Embodiment-3, and showing particularly a schematic structure of the device assembled on said substrate. In Fig. 4, 101 is a substrate, 102 is a comb-electrode, 103 is electrode pads, 104a is a top of conductive bump, 104b is a base of said conductive bump, 105 is conductive adhesive, 106 is insulating adhesive, 107 is a package, 108 is an electrode pattern, 112 is a protecting means, and 113 is a direct bonding part. and 114 is an insulation layer.

In Embodiment-3, like the case of Embodiment-1, 36° Y-cut X-propagation lithium tantalate crystals are used both as substrate 101 and protection means 112. However, similar effects can be obtained by employing a single crystal substrate of lithium niobate, quartz crystal, lithium borate, or such. On the other hand, comb-electrode 102 and electrode pads 103 of metal thinfilm made mainly of gold are formed by using a conventional photolithographic (lift-off) method. Furthermore, a silicon oxide layer as an insulation layer 114 is deposited for a thickness of about 2 μm on the area of direct bonding by a sputtering method. As a material of insulation layer 114, silicon can be used instead of silicon oxide. In here, the thickness of insulation layer 114 is made much thicker than that of comb-electrode 102 so that the step of wiring electrode is adequately covered.

By employing an adequately thick insulation layer 114, the stress effected on the substrate can be relieved. That is, the stress produced at the direct bonding can be relieved so that the negative effect of stress on the characteristics of acoustic surface-wave device can be eliminated.

In order to undisturb the propagation of surface-wave, an indentation is provided on protecting means 112 on a part facing to comb-electrode 102 of substrate 101 by using fluoro-nitric acid system etchant. In here, the direct bonding of substrate 101 onto protecting means 112 is performed by the method shown in Embodiment-1.

The direct bonding in Embodiment-3 is conducted at the boundary between the 36° Y-cut X-propagation lithium tantalate crystal constituting the protecting means and the silicon oxide layer constituting the insulation layer. Since the direct bonding is fundamentally a technology applicable to the bonding of different materials, an excellent bonding can be obtained in this case where the components of same materials are bonded like the case of Embodiment-1.

Although not shown in the drawing, there should be region where a wiring pattern exists between the comb-electrode 102 of acoustic surface-wave device and the electrode pad 103. In this case, therefore, there should be a step or a gap between the wiring part and none-wiring part so that no perfect hermetic seal equivalent to direct bonding can not be obtained. Therefore, when this step can be a problem, said protecting means is directly bonded after insulating layer 114 is leveled out by applying a chemical and mechanical polishing, securing a hermetic sealing of higher degree. In this case, the conventional package would be not be required, producing an extra effect of more compact acoustic surface-wave device realized at a lower cost.

In Embodiment-3, though a single crystal substrate same as said substrate on which acoustic surface-wave device is constituted is utilized as the protecting means, a glass substrate having a thermal expansion coefficient same at that of said substrate on which said acoustic surface-wave device is disposed and enabling the direct bonding to said insulation layer can be used. Moreover, a quartz crystal substrate bondable easily to said insulation layer made of silicon oxide may be used.

Then, conductive bumps 104 are formed on electrode pad 103 disposed on substrate 101 by a ball-bonding method using gold wire, and conductive adhesive 105 is transfer-coated on said conductive bumps 104 after leveling the height of the bumps. After this, substrate 101 is face-down bonded by using conductive adhesive 105. Since the bonding strength realized by using only conductive bump 104 and conductive adhesive 105 is not adequate to hold down substrate 101, insulating resin 106 is filled in the space provided between package 107 and holding substrate 112 bonded directly on substrate 101 in order to fortify the adhesive strength by utilizing the stress of insulating resin 106 at hardening.

In Embodiment-3, since comb-electrode 102 disposed on substrate 101 is provided with an indentation formed on protecting means 112, the conventionally needed viscosity adjustment of insulating adhesive is not necessary, and the space is filled completely with the low-viscosity insulating adhesive.

As above described, the acoustic surface-wave derive of the invention consists of a substrate, a comb-electrode disposed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, insulating protection layer disposed on said comb-electrode surrounding said comb-electrode between said comb-electrode and said plural electrode pads, protecting means covering said comb-electrode enclosing a space produced by performing substantially covalent bonding of said substrate to said comb-electrode and said plural electrode pads, conductive bumps disposed on said plural electrode pads, conductive adhesive disposed at least on the top of said conductive bumps, package adhered on said conductive bumps by said conductive adhesive, and insulating adhesive filled to contact with said conductive bumps, said protecting means, and said package. By this, the face-down system bonding can be applied even when the comb-electrode made of easily corroded aluminum alloy is employed obtaining compact and low profile acoustic surface-wave device can be obtained easily.

That is, with the conventional process assembling the acoustic surface-wave device, the viscosity adjustment and the coating processes of insulating resin had been difficult, and those can be eliminated by using a low viscosity insulating resin filling the space provided under the protecting means so that a higher production yield while a lower production cost can be obtained. By providing the protecting means, introduction of conductive foreign material during the assembling process can be completely prevented.

Since the thermal stress due to the difference in the thermal expansion coefficients between the substrate and the protecting means can be absorbed in this embodiment, the acoustic surface-wave device of excellent frequency characteristics can be obtained also.

Moreover, the conventionally needed package can be eliminated since the sealing of comb-electrode is realized by said protecting means and by leveling said insulation layer.

Embodiment-4

Fig. 5 shows a schematic cross-section of the invented acoustic surface-wave device of Embodiment-4, and showing particularly a schematic structure of the device assembled on said substrate. In Fig. 5, 101 is a substrate, 102 is a comb electrode, 103 is electrode pads, 104a is a top of conductive bump, 104b is a base of said conductive bump, 105 is conductive adhesive, 106 is insulating adhesive, 107 is a package, 108 is an electrode pattern, 112 is a protecting means, and 113 is a direct bonding part. and 114 is an insulation layer.

In Embodiment-4, like the case of Embodiment-1, 36° Y-cut X-propagation lithium tantalate crystals are used as substrate 101 and protection means 112. However, same effects could be obtained by employing a single crystal substrate of lithium niobate, quartz, lithium borate, or such. On the other hand, comb electrode 102 and electrode pads 103 made of metal thinfilm made mainly of gold are formed by using a conventional photolithographic (lift-off) method. Furthermore, a pattern of silicon oxide layer acting as an insulation layer surrounding comb-electrode is deposited on substrate 101 and this is acting as a spacer in order to indisturb the propagation of surface-wave.

In here, said insulation layer is deposited for a thickness of about 2 μm which is considerably thicker than the thickness of comb-electrode. Though a sputtering method is used to deposit said silicon oxide pattern here, a coated type insulation layer may be used because of its excessive sputtering period. The direct bonding between substrate 101 and protecting means 112 on which insulation layer 114 is deposited is performed by the method described in Embodiment-3. Since the direct bonding in Embodiment-4 is performed at the boundary between the 36° Y-cut X-propagation lithium tantalate crystal and the insulation layer deposited on said protecting means, excellent bonding can be obtained like the case of Embodiment-1.

Although a single crystal substrate identical with the substrate on which the acoustic surface-wave device is constructed is used as a protecting means, a glass substrate having a thermal expansion coefficient same as that of acoustic surface-wave device and a high bondability to said insulation layer may be used as well. Moreover, a quartz crystal substrate having a thermal expansion coefficient same as that of said insulation layer made of silicon oxide may also be used.

In Embodiment-4, a flat plate type protecting means 112 is used since a space against said comb-electrode is automatically provided by means of insulation layer 114 and no indentation has to be provided on protecting means 112, the production cost can be reduced further.

Then in next, conductive bumps 104 are formed on electrode pad 103 disposed on substrate 101 by a ball-bonding method using gold wire, and conductive adhe-

sive 105 is transfer-coated on said conductive bumps 104 after leveling the heights of bumps. After this, substrate 101 is face-down bonded by using conductive adhesive 105. Since the bonding strength obtained by conductive bump 104 and conductive adhesive 105 only is not adequate to hold down substrate 101, insulating resin 106 is filled in the space provided between package 107 and substrate 101 in order to fortify the adhesive strength by utilizing the shrinkage stress of insulation resin 106 at hardening.

In Embodiment-4, since comb-electrode 102 disposed on substrate 101 is provided with an indentation formed on protecting means 112, the conventionally needed viscosity adjustment of insulation adhesive is not necessary, and the space is filled completely with the low-viscosity insulation adhesive.

As above described, the acoustic surface-wave derive of the invention consists of a substrate, a comb-electrode disposed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, an insulation layer disposed on said comb-electrode surrounding said comb-electrode between said comb-electrode and said plural electrode pads, a protecting means covering said comb-electrode enclosing a space produced by performing a substantially covalent bonding of said substrate to said comb-electrode and said plural electrode pads, conductive bumps disposed on said plural electrode pads, conductive adhesive disposed at least on the top of said conductive bumps, a package adhered on said conductive bumps by means of said conductive adhesive, and an insulation adhesive filled to contact with said conductive bumps, said protecting means, and said package. By this, a face-down system bonding is applied here attaining a compact and low profile acoustic surface-wave device easily.

That is, with the conventional process assembling the acoustic surface-wave device, the viscosity adjustment and the coating processes of insulating resin had been difficult. Those can be eliminated by using a low viscosity insulating resin filling the space provided under the protecting means. Therefore, the production yield can be higher while the production cost can be lower. By providing said protecting means, introduction of conductive foreign objects during the assembling process can be prevented completely.

Since said flat-plate shaped protecting means is realized by depositing a thick insulating means, so that the process to provide an indentation can be eliminated, reducing further the production cost and expanding the range of choice of substrate materials.

Moreover, like the present embodiment of the invention, by providing a thick insulation layer, the thermal stress due to the difference in the thermal expansion coefficients between the substrate and the protecting means can be absorbed in this embodiment, an acoustic surface-wave device of excellent frequency characteristics can be obtained.

Moreover, by disposing a thick insulating means at the direct bonding part of substrate and by leveling said insulating means, the better sealing of said comb-electrode can be obtained by said protecting means only. In this case, the conventionally needed package can be eliminated, realizing a more compact acoustic surface-wave device at a still lower cost.

Embodiment-5

Fig. 6 shows a schematic cross-section of the invented acoustic surface-wave device of Embodiment-5, and showing particularly a schematic structure of the device assembled on said substrate. In Fig. 6, 101 is a substrate, 102 is a comb-electrode, 103 is electrode pads, 104a is a top of conductive bump, 104b is a base of said conductive bump, 105 is a conductive adhesive, 106 is an insulating adhesive, 107 is a package, 108 is an electrode pattern, 112 is a protecting means, 113 is a direct bonding part, 113 is an insulating protection means, and 114 is an insulation layer.

In Embodiment-5, 41° Y-cut X-propagation lithium niobate crystals are used as substrate 101 and protection means 112. On the other hand, comb electrode 102 and electrode pads 103 made of metal thinfilm made mainly of an alunimum alloy are formed by using a conventional photolithographic method. Furthermore, insulating protection layer 113 is formed on an area where no metal thinfilm acting as a protecting layer is formed on the electrode region made of aluminum alloy, that is, surrounding the direct bonding area and comb-electrode 102. By this, the possible corrosion of comb-electrode 102 during said direct bonding process is prevented, so that the application of direct bonding process is possible even when a comb-electrode made of aluminum alloy is used.

An air-tight sealing can be obtained when said protecting means is bonded directly onto insulation layer 114 after its leveled out by applying a mechanical polishing. Moreover, a pattern of silicon oxide insulation layer acting as a spacer surrounding said comb-electrode 102 is disposed on a part of substrate 101 facing to comb-electrode 102 in order to undisturb the propagation of acoustic surface-wave.

In here forming said silicon oxide layer, like Embodiment-4, a sputtering method is used. The direct bonding of substrate 101 and protecting means 112 on which insulation layer 114 is disposed is performed by a method described in Embodiment-3. Though the direct bonding shown in Embodiment-5 is performed at a boundary between the insulation protecting layer formed on a 41° Y-cut X-propagation lithium niobate crystal acting as a substrate and the insulation layer formed on said protecting means, excellent bonding like the one obtained with Embodiment-1 can be obtained.

Though In Embodiment-5, a single crystal substrate identical with the substrate on which the acoustic surface-wave device is constructed is used as a protecting means, a glass substrate having a thermal expan-

sion coefficient same as that of acoustic surface-wave device substrate and high bondability to said insulation layer may be used as well. Moreover, a quartz crystal substrate having a thermal expansion coefficient same as that of said insulation layer made of silicon oxide may be used also.

Then in next, conductive bumps 104 are formed on electrode pad 103 disposed on substrate 101 by a ball-bonding method using gold wire, and conductive adhesive 105 is transfer-coated on said conductive bumps 104 after leveling the heights of bumps. After this, substrate 101 is face-down bonded by using conductive adhesive 105. Since the bonding strength attainable by conductive bump 104 and conductive adhesive 105 only is not adequate to hold down substrate 101, insulating resin 106 is filled in the space provided between package 107 and substrate 101 in order to incease the adhesive strength by utilizing the shrinkage stress of insulating resin 106 at hardening.

In Embodiment-4, since comb-electrode 102 disposed on substrate 101 is provided with said indentation formed on protecting means 112, the conventionally needed viscosity adjustment of insulating adhesive is unnecessary, and the space can be filled completely with the low-viscosity insulating adhesive.

As above described, the acoustic surface-wave derive of the invention consists of a substrate, a comb-electrode disposed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, insulating protection layer disposed on said comb-electrode, an insulation layer disposed surrounding said comb-electrode between said comb-electrode and said plural electrode pads, a flat protecting means covering said comb-electrode through a space produced by performing a substantially covalent bonding of said substrate to said insulating means, conductive bumps disposed on said plural electrode pads, conductive adhesive disposed at least on the top of said conductive bumps, package adhered on said conductive bumps by means of said conductive adhesive, and an insulating adhesive filled to contact with said conductive bumps, said protecting means, and said package. By this, said face-down system bonding is applied attaining a compact and low profile acoustic surface-wave device easily.

That means that, with the conventional process assembling the acoustic surface-wave device, the viscosity adjustment and the coating processes of insulating resin which were left as difficult problems, those can be eliminated completely by using a low viscosity insulating resin filling the space provided under the protecting means so that a higher production yield while a lower production cost can be obtained. By providing said protecting means, introduction of conductive foreign particles during the assembling process can be prevented.

Moreover, since a flat plate-shaped protecting means can be realized by depositing a thick insulating means, the process to provide an indentation on said protecting means can be eliminated reducing further the production cost and expanding the range of choice of substrate materials.

In additon to these, like the present embodiment of the invention, by providing a thick insulation layer, the thermal stress produced by the difference in the thermal expansion coefficients between the substrate and the protecting means can be absorbed in here, so that an acoustic surface-wave device of excellent frequency characteristics can be produced.

Furthermore, by depositing an insulation layer on the direct bonding region of substrate and leveling said insulation layer, a high degree sealing of comb-electrode can be obtained by said protecting means only. In this case, the conventionally needed package becomes unnecessary attaining a more compact and lower cost acoustic surface-wave device.

Claims

1. An acoustic surface-wave device comprising; a comb-electrode formed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, a protection means covering said comb-electrode through a space formed by a substantially covalent bonding established between said comb-electrode and said plural electrode pads, conductive bumps formed on the tops of said plural electrode pads, a conductive adhesive layer disposed at least on the tops of said conductive bumps, a package adhered on said conductive bums by means of said conductive adhesive, and insulating adhesive contacting with said conductive adhesive, said conductive bumps, and said protection means, filling said package.

2. An acoustic surface-wave device according to Claim 1; wherein an indentation is provided in said protecting means at a region facing to said comb-electrode region.

3. An acoustic surface-wave device according to Claim 1; wherein said protecting means consists of a single crystal same as that of said substrate.

4. An acoustic surface-wave device according to Claim 1; wherein an insulating protection layer is formed on said comb-electrode.

5. An acoustic surface-wave device according to Claim 1; wherein said insulating protection means consists of an inorganic material of either silicon or silicon oxide.

6. An acoustic surface-wave device according to Claim 1; wherein said conductive bump consists of a base bonded to said electrode pad and a protrusion formed on said base where said the height of

said base is lower than the height of said protecting means.

7. An acoustic surface-wave device comprising; a comb-electrode formed on the main surface of said substrate, plural electrode pads disposed on the peripheral of said comb-electrode, an insulating layer formed to surround said comb-electrode at an area between said comb-electrode and said plural electrode pads, a protection means covering said comb-electrode through a space formed by a substantially covalent bonding established between said comb-electrode and said plural electrode pads, a conductive bumps formed on the tops of said plural electrode pads, a conductive adhesive layer disposed at least on the tops of said conductive bumps, a package adhered on said conductive bumps by means of said conductive adhesive, and an insulating adhesive contacting with said conductive adhesive, said conductive bumps, and said protection means, filling said package.

8. An acoustic surface-wave device according to Claim 7; wherein said insulation layer is made of an inorganic material of either silicon or silicon oxide.

9. An acoustic surface-wave device according to Claim 7; wherein an indentation is provided on said protecting means at an area facing to said comb-electrode.

10. An acoustic surface-wave device according to Claim 7; wherein said protection means is made of a single crystal same as that of said substrate.

11. An acoustic surface-wave device according to Claim 7; wherein said protection means is made of either quartz or glass.

12. An acoustic surface-wave device according to Claim 7; wherein an insulating protection layer is formed on said comb-electrode.

13. An acoustic surface-wave device according to Claim 12; wherein said insulating protection layer is made of inorganic material of wither silicon or silicon oxide.

14. An acoustic surface-wave device according to Claim 7; wherein said conductive bump consists of a base bonded to said electrode pad and a protrusion formed on said base, and the height of said base is lower than the height of protecting means.

15. A manufacturing method of acoustic surface-wave device comprising; a process to form a comb-electrode on said substrate, a process to form plural electrode pads on said substrate, a process of substantially covalent bonding covering said substrate and said protecting means through a closed space formed between said comb-electrode and said plural electrode pads, a process to form conductive bupms on said plural electrode pads, a process to form a conductive adhesive layer at least on the tops of said conductive bumps, a process to adhere said conductive bumps on to said electrode pattern disposed on said package, and a process to fill said package contacting with said conductive bymps, said donductive adhesive, and said protecting means.

16. A manufacturing process of acoustic surface-wave device according to Claim 15 including a process to form an insulating protection layer is formed on said comb-electrode.

17. A manufacturing method of acoustic surface-wave device comprising; a process to form a comb-electrpode on said substrate, a process to form plural electrode pads on said substrate, a process to form an insulation layer surrounding said comb-electrode at a region between said comb-electrode and said plural electrode pads, a process to perform a substantially covalent bonding between said conductive bumps and said protecting means through a closed space, a process to coat a conductive adhesive kayer at least at the tops of said conductive bumps, a process to adhere said conductive bumps on said electrode pattern disposed on a package by means of said conductive adhesive, and a process to fill said package with an insulating adhesive in contact with said conductive bumps, said conductive adhesive, and said protecting means.

18. A manufacturing method of acoustic surface-wave device according to Claim 17; including a process forming an insulating protection layer on said comb-electrode.

19. A manufacturing method of acoustic surface-wave device comprising; a process to form a comb-electrpode on a substrate, a process to form plural electrode pads on said substrate, a process to form an insulation layer to surround said comb-electrode at a region between said comb-electrode and said plural electrode pads, a process to level the surface of said insulation layer, a process to bond substantially covalently said conductive bumps and said protecting means through a closed space, a process to coat conductive adhesive at least at the top of said conductive bumps, a process to adhere said conductive bumps on said electrode pattern disposed on a package by means of said conductive adhesive, and a process to fill an insulating adhesive to contact with said conductive bumps, said conductive adhesive, said protecting means, and said package.

20. A manufacturing process of surface-wave device according to Claim 19; including a process to form an insulating protection layer on said comb-electrode.

Fig. 1

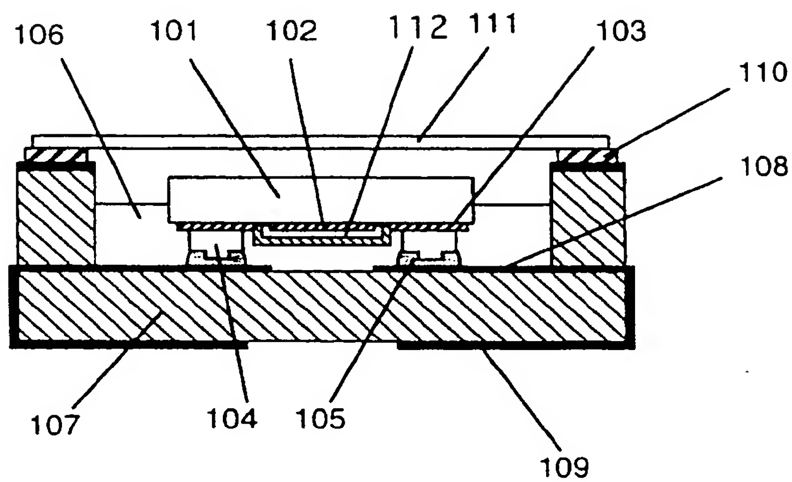


Fig. 2

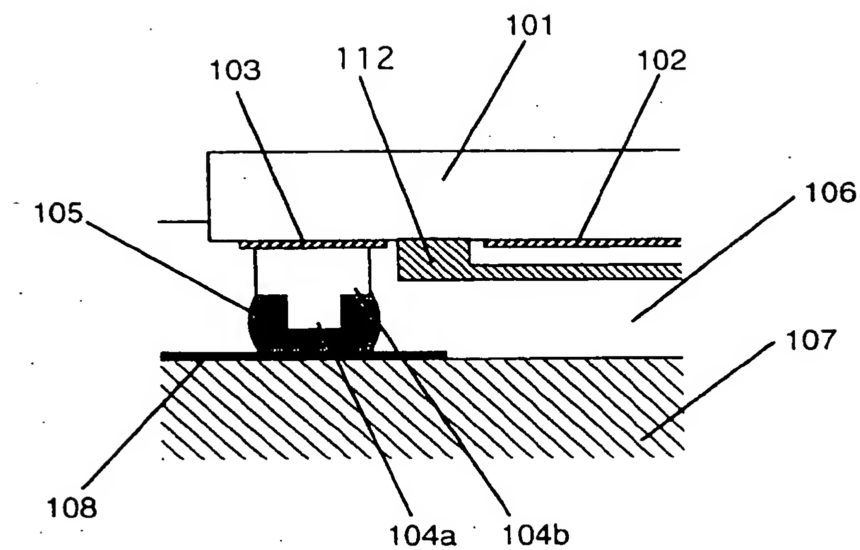


Fig. 3

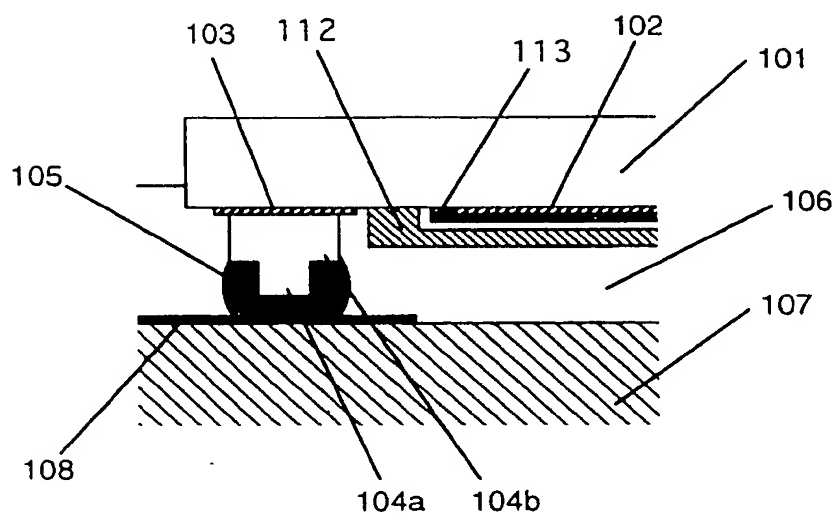


Fig. 4

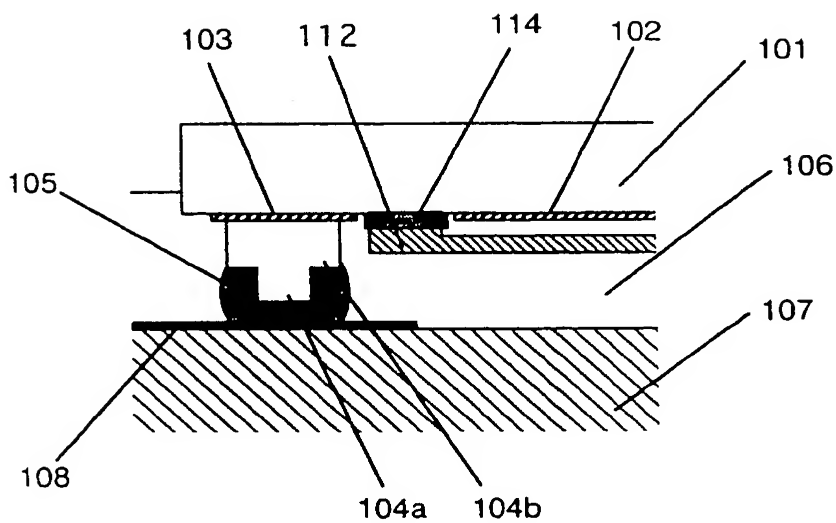


Fig. 5

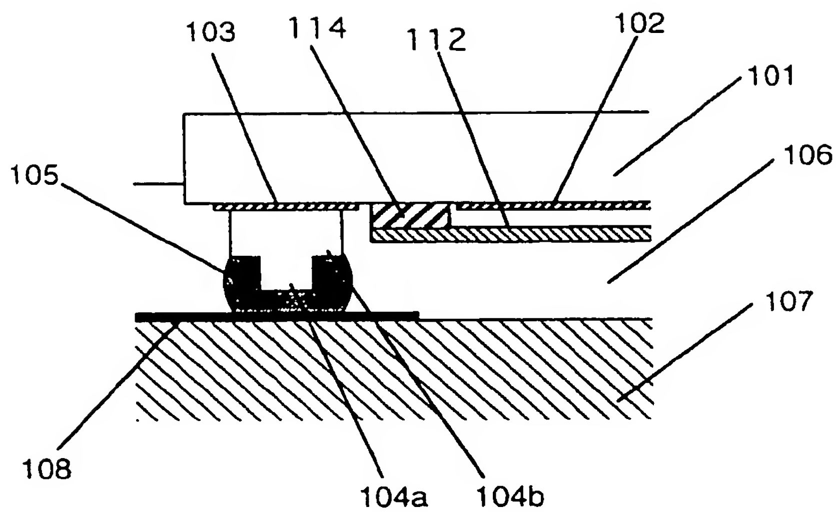


Fig. 6

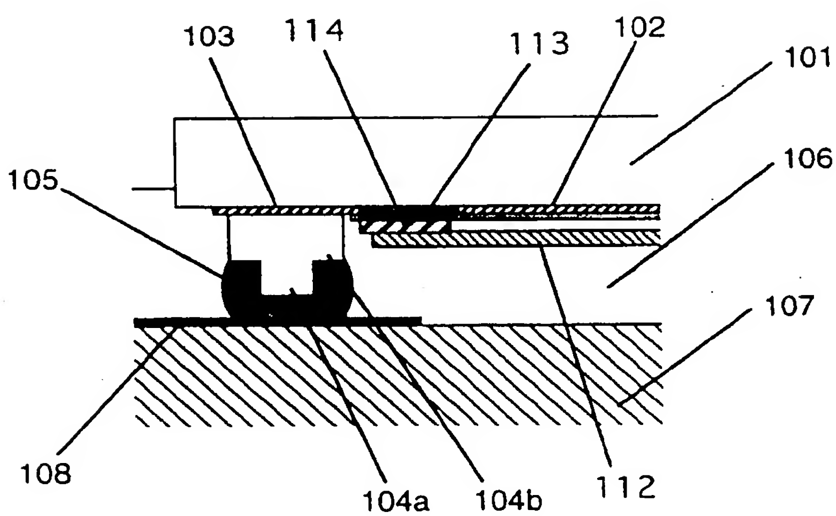
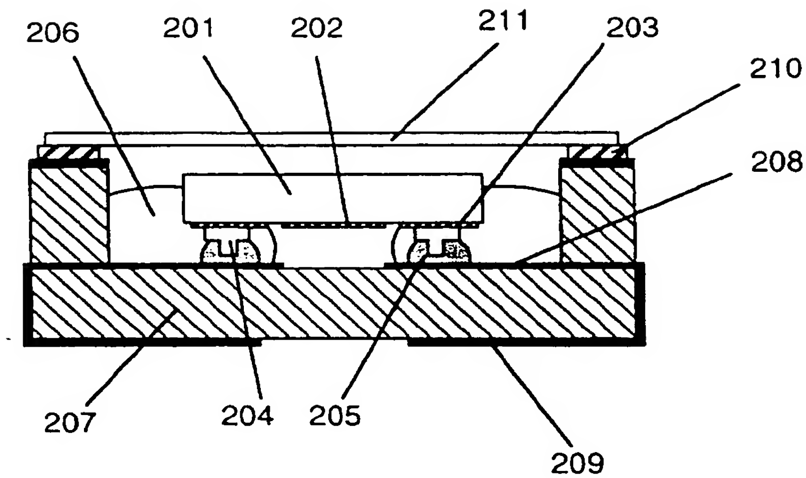


Fig. 7

Prior Art



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 7281

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	JEE JOURNAL OF ELECTRONIC ENGINEERING, vol. 30, no. 324, 1 December 1993, pages 36-39, XP000422117 KAZUO EDA ET AL: "FLIP-CHIP BONDING TECHNOLOGY FABRICATES GHZ-BAND SAW FILTERS" * page 37, middle column, line 1 - page 38, middle column, line 6; figure 4 * ---	1	H03H9/05
A	DE-A-43 02 171 (BE & WE BESCHAEFTIGUNGS UND WE) 28 July 1994 * column 2, line 44 - column 3, line 35; figure 5 * ---	1	
A	EP-A-0 622 897 (MATSUSHITA ELECTRIC IND CO LTD) 2 November 1994 * example 1 * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 95, no. 004 & JP-A-07 111438 (HITACHI LTD), 25 April 1995, * abstract * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H03H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 August 1996	D/L PINTA BALLE.., L

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